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Citation for published version:
Major, JT, Johnson, W & Deary, IJ 2014, 'Linear and Nonlinear Associations Between General Intelligence and Personality in Project TALENT', *Journal of Personality and Social Psychology*, vol. 106, no. 4, pp. 638-654. https://doi.org/10.1037/a0035815

Digital Object Identifier (DOI):
10.1037/a0035815

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
Journal of Personality and Social Psychology

Linear and Nonlinear Associations between General Intelligence and Personality in Project TALENT

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Keywords: Intelligence-personality associations, intelligence, personality, Project TALENT, quadratic associations; gifted

Abstract

Research on the relations of personality traits to intelligence has primarily been concerned with linear associations. Yet, there are no a priori reasons why linear relations should be expected over nonlinear ones, which represent a much larger set of all possible associations. Using two techniques, quadratic and generalized additive models, we tested for linear and nonlinear associations of general intelligence (*g*) with ten personality scales from Project TALENT (PT), a nationally-representative sample of approximately 400,000 American high school students from 1960, divided into four grade samples. We departed from previous studies, including one with PT (Reeve, Meyer & Bonaccio, 2006), by modeling latent quadratic effects directly, controlling the influence of the common factor in the personality scales, and assuming a direction of effect from *g* to personality. Based on the literature, we made seventeen directional hypotheses for the linear and quadratic associations. Of these, 53% were supported in all four male grades and 58% in all four female grades. Quadratic associations explained substantive variance above and beyond linear effects (mean R^2 between 1.8% and 3.6%) for Sociability, Maturity, Vigor and Leadership in males, and Sociability, Maturity and Tidiness in females; linear associations were predominant for other traits. We discuss how suited current theories of the personality-intelligence interface are to explain these associations, and how research on intellectually gifted samples may provide a unique way of understanding them. We conclude that nonlinear models can provide incremental detail regarding personality and intelligence associations.

Introduction

Intelligence and personality are important predictors of behavior and outcomes in many domains, notably in educational and occupational settings (Barrick & Mount, 1991; Hunt, 2011). In addition, there are some associations between intelligence and personality traits (Ackerman & Heggestad, 1997; DeYoung, 2011). Within the Big Five framework, general intelligence (*g*) is most strongly associated with Openness to Experience (r = .33 in the meta-analysis of Ackerman & Heggestad, 1997). This connection may seem obvious since measures of Openness to Experience typically include items assessing engagement in intellectual pursuits, and because intelligence has often been held to be the cognitive part of personality (Cattell, 1950; DeYoung, 2011; Guilford, 1959). Nonetheless, intelligence is also related to personality traits that are considered the least cognitive, such as Neuroticism and Extraversion (DeYoung, 2011). Neuroticism has consistently shown modest negative correlations with general intelligence (r = -.15 in Ackerman & Heggestad, 1997), and most recent studies (performed after the year 2000) have found that Extraversion also has a small but significant negative association with *g*, in the range of r = -.04 to -.11 (Luciano, Leisser, Wright, & Martin, 2004; Moutafi, Furnham, & Paltiel, 2005; Soubelet & Salthouse, 2011; Wolf & Ackerman, 2005). In addition, DeYoung (2011) found that in 8 studies not included in Ackerman and Heggestad’s (1997) meta-analysis, Conscientiousness had a mean N-weighted correlation of -.12 with intelligence.

Nevertheless, some researchers have argued that the theoretical implications of these personality-intelligence correlations are limited due to their small size or inconsistency across studies (Eysenck, 1994; Soubelet & Salthouse, 2011; Zeidner, 1995). One possibility is that some intelligence-personality associations could be nonlinear, and thus missed by traditional linear analyses (Austin, Deary, & Gibson, 1997; Austin et al., 2002; Eysenck & White, 1964; Reeve, Meyer, & Bonaccio, 2006). Findings in this area have, however, have often been negative. Austin et al. (1997) found evidence for positive quadratic effects (U-shaped) of Neuroticism and Openness to Experience on intelligence in one sample, but Austin et al. (2002) did not find any significant effects of this kind for the Big Five and Eysenck's Big Three in four other datasets. There are three theoretical and methodological issues surrounding these results.

First, different theories make alternative causal predictions about personality-intelligence relations. For example, Ackerman's PPIK theory (intelligence-as-process, personality, interests, and intelligence-as-knowledge) predicts that intelligence becomes related to personality through cognitive investment in four trait complexes which involve different personality traits and interests (Ackerman, 1996; Ackerman & Beier, 2003). Alternatively, Chamorro-Premuzic and Furnham (2006) proposed that personality-intelligence relations can be conceptualized as the influence of personality traits on intellectual competence, where intellectual competence is defined as "an individual's capacity to acquire and consolidate knowledge throughout the life span" (p. 259, Chamorro-Premuzic & Furnham, 2006). PPIK theory suggests that cognitive factors causally contribute to broader constellations involving personality and interests (trait complexes), and thus that the association between all the variables is an emergent property due to reciprocal causation between all three variables. In contrast, Chamorro-Premuzic and Furnham's theory proposes that personality traits directly influence the development of intelligence. A third possibility is that intelligence contributes directly to the development of personality through conscious perceptions of adaptive benefit of particular behaviours, or through the influence of intelligence on motivations involved in personality.

When examining only linear effects, it is difficult to distinguish these possibilities without a longitudinal design, because effects are typically symmetrical no matter which ways the causal arrows are drawn. However, nonlinear analyses can pick up larger effects in one direction (e.g. there might be a quadratic effect of intelligence on Extraversion but no quadratic effect of Extraversion on intelligence), which can suggest that causal forces operated in this direction. Previous studies of quadratic effects have focused on the quadratic effects of personality on intelligence (Austin et al., 1997; Austin et al., 2002); however, in the current study we assessed quadratic effects of intelligence on personality.

The second issue surrounding nonlinear personality-intelligence relations is that previous nonlinear studies were not performed with latent variables as predictors but with observed scores (Austin et al., 1997; Austin et al., 2002; Reeve et al., 2006). This limited their power because the size of the quadratic effect was not corrected for unreliability. Quadratic terms are particularly sensitive to unreliability of the predictor variable (Moosbrugger, Schermelleh-Engel, Kelava, & Klein, 2009). Methodological researchers have observed that even using factor scores for the predictor can produce biased estimates of structural model parameters due to residual measurement error (Bartholomew, 1987; Harring, Weiss, & Hsu, 2012). Harring et al. (2012) found that, compared with methods that model latent quadratic terms directly, the use of factor scores for led to substantial underestimation of quadratic coefficients.

A third issue is that to detect quadratic effects with small effect sizes, large sample sizes are needed. Under simulation, Harring et al. (2012) showed that for a medium-sized quadratic effect that accounted for 5% of the variance, even a small sample size of 50 was sufficient to obtain power over .80. However, in practice, quadratic or interaction effects can be considerably smaller than this, accounting for only 1% or 2% of the variance. To find these effects, very large sample sizes (i.e. of 500 or greater) are necessary. For example, Moosbrugger et al. (2009) found that for a quadratic effect size of 2% and a sample size of 400, average power was only 76% using latent estimation (power would be less with non-latent methods). Thus, the sample of Austin, Deary & Gibson (1997) and two of the four samples in Austin et al. (2002) may not have had sufficient power to detect small quadratic effects.

Reeve, Meyer and Bonaccio (2006) conducted one study on personality-intelligence relations that was sufficiently powered. Their study is directly relevant to ours as we made use of the same sample. Reeve et al. (2006) used a subsample of data from Project TALENT (PT), a nationally-representative study of approximately 400,000 American high school students in 1960. The sample in Reeve et al. (2006) consisted of 71,887 students in their final year of high school (seniors), with a mean of age 17.2 years (SD = 1.3). The ten PT personality scales were developed specifically for PTin the late 1950s, before there was much consensus about models of personality structure. The scales used thus do not correspond directly to the Big Five framework in common usage today, but Reeve et al. (2006) related the scales to the Big Five by two methods. First, the three authors independently examined each scale’s content and compared it to the content of the NEO-PI-R scales (Costa & MacCrae, 1992), and second, they re-administered the PT personality scales and IPIP scales for the Big Five to a sample of 219 college students. Table 1 summarizes the NEO-PI-R facet with which each PT scale was most closely associated (by rater consensus), as well as with which Big Five trait(s) the scales loaded in a joint factor analysis with IPIP scales (Reeve et al., 2006).

These relations provided a way to link the PT scales to the larger literature on personality-intelligence relations, which has frequently been organized according to the Big Five (e.g., Ackerman & Heggestad, 1997; Austin et al., 2002). The facet-matching by Reeve and colleagues may be limited due to imperfect content overlap, but the majority of the PT scales displayed good convergent validity with the Big Five factors predicted to subsume them (factor loadings = .42 to .81). In addition, the content of the PT scales was facet-like;

hence they could be viewed as analogous to facets of the Big Five, with the exception that some scales (e.g. Self-Confidence) would be facets of more than one Big Five factor.

Reeve et al. (2006) found that *g* correlated positively and substantively (above .15 in their definition) with the scales Mature Personality, Calmness, and Self-Confidence in grade 12 males. These correlations were also observed in grade 12 females, where Culture and Social Sensitivity were also correlated positively with *g*. These associations may, however, have been influenced by measurement artefacts because the PT personality scales were nearly uniformly positively correlated with each other. The mean of the inter-scale correlations in the senior sample was .38 in males, and .35 in females (SD = .14 in both samples). Reeve et al. (2006) did not address this common variance among personality scales (similar factors in other personality inventories have been termed ‘general factors of personality’; Rushton & Irwing (2008)). This common variance was relevant because it correlated positively with *g* in Project TALENT (mean r = .28 in all samples), and thus we predicted that it would affect the correlations of the personality scales with *g*.

Recent research has suggested that the common variance between Big Five measures is in large part due to rater bias. In a meta-analysis of 45 multi-trait multi-method samples, Chang, Connelly and Geeza (2012) found that much of the common variance between Big Five personality scales is due to method variance specific to raters, which likely includes response biases such as socially desirable responding. After rater effects were controlled for in the CTOM (correlated traits, orthogonal methods) model, adding a general factor of personality (GFP) above the Big Five factors resulted in a substantial decrement in model fit compared the model allowing free covariance between the Big Five (Chang et al. 2012). Moreover, the GFP had non-substantive loadings from Extraversion (.03) and Openness to Experience (-.09), supporting the view that there is no single factor that sits above the Big Five in multi-informant data (however, a model with Digman’s Alpha and Beta were still found to be plausible). A number of studies have now supported the conclusion that the GFP emerges for artifactual methodological reasons (Anusic, Schimmack, Pinkus, & Lockwood, 2009; Ashton, Lee, Goldberg, & de Vries, 2009; Bäckström, Björklund, & Larsson, 2009; de Vries, 2011).

As detailed further below, we also observed that several of the PT scales in Reeve et al. (2006), and in our initial analysis, displayed stronger positive correlations with *g* than were expected based on such correlations in the Big Five under which the PT scales could be assigned. This, combined with the moderate correlation of the common factor to *g*, suggested that it may have acted as a confounder in the estimates. Because we were primarily interested in the relations of the individual scales to *g*, and wished to err on the side of under-estimation rather than over-estimation, we conducted two separate analyses: one with the original personality data and one while controlling for the common factor.

In addition to linear associations, Reeve et al. (2006) looked for nonlinear relations by converting the personality scores into extremeness scores and examining their correlations with *g* factor scores. Reeve et al. (2006) did not observe any correlations between the extremeness scores and *g* above a selected cut-off of .15. However, there were two limitations to their method of looking for quadratic effects. First, whereas extremeness scores ($|X- Mean_x|$) may suggest the presence of quadratic trends, they are not equivalent to examining true quadratic effects which predict scores with the form $|X^2-Mean_x|$. Second, Reeve et al. (2006) chose to convert the personality scale scores rather than the intelligence test scores in PT to extremeness scores, thus examining the effect of extreme personality on intelligence (Rosenthal & Rosnow, 1991). This is the same direction of effect investigated by Austin and colleagues (Austin et al., 1997; Austin et al., 2002). As noted, we were instead interested in examining the effects of intelligence on personality. This had the added advantage of greater power, due to the greater reliability of the latent *g* factor compared to the observed personality scales.

The aim of our study was thus to re-examine linear and nonlinear relations between *g* and personality in Project TALENT. Moreover, we used structural equation modeling (SEM), which avoids using factor scores and allows for direct estimation of latent linear and quadratic effects (Klein & Moosbrugger, 2000). We also used generalized additive models (GAMs; Hastie & Tibshirani, 1986) to explore further possible nonlinear trends. The PT data were suited to our aims because of its large and relatively population-representative sample of nearly 400,000 high school students in four grades, allowing for the possibility of replication across grade subsamples. However, one potential limitation of using this young sample was that less able students may not have fully understood some of the more abstract personality items, limiting their reliability.

Linear Personality-Intelligence Associations in Project TALENT

We focused on the personality-intelligence literature (primarily on the Big Five) in generating our hypotheses about specific associations.

Openness to Experience displays a positive correlation with IQ (Ackerman & Heggestad, 1997; DeYoung, 2011), and the two PT scales that loaded significantly on Openness to Experience were Culture and Leadership (Reeve et al., 2006). Neither scale is a pure measure of Openness/Intellect (see Table 1); therefore, we hypothesized that their correlations with *g* would be positive, although we expected them to be smaller in size than the .33 value in the meta-analysis of Ackerman and Heggestad (1997). The correlation of Openness to Experience tends to be higher with verbal ability than non-verbal ability; verbal intelligence likely accounts for a large part of its association with *g* (Ashton, Lee, Vernon, & Jang, 2000).

Five of the ten scales in PT had primary loadings on Extraversion, which in recent studies has typically shown small negative associations with intelligence (Wolf & Ackerman, 2005; Moutafi et al., 2005; Austin et al., 2002). However, this relation has not been uniform for all facets of Extraversion. Wolf and Ackerman (2005) suggested that Extraversion should be split to reflect two different aspects: social closeness (the need for intimacy) and social potency (the need for making an impact on others). They also hypothesized that "Individuals high on social closeness may be less likely to invest their time in intellectually engaging tasks, leading to lower scores on intelligence tests" (p. 533, Wolf & Ackerman, 2005). Partially consistent with this, their meta-analysis of 48 samples showed that the correlation between social potency and intelligence was slightly positive ($r = .04$, $p < .05$), whereas the intelligence association with social closeness was not significantly different from zero ($r = -.01$) (Wolf & Ackerman, 2005). Similarly, Pincombe, Luciano, Martin & Wright (2007) found that the excitement-seeking and gregariousness facets of NEO Extraversion correlated negatively with IQ ($r = -.09$ and $r = -.15$, respectively). We thus anticipated that PT Sociability and Impulsiveness scales would show negative associations with intelligence (due to their face-value relations with social closeness and excitement-seeking), whereas Vigor, Self-Confidence and Leadership would show positive associations (due to their face-value relations with social potency).

The Big Five trait Neuroticism has a negative correlation with intelligence (Ackerman & Heggestad, 1997; DeYoung, 2011). Based on their face-value contents, and the findings of Reeve et al. (2006), the PT scales of Calmness and Self-Confidence represent the converse of Neuroticism (Emotional Stability); therefore, we predicted these scales would display positive associations with intelligence.

The literature has suggested that Big Five Conscientiousness has a small negative association with intelligence (DeYoung, 2011; Moutafi, Furnham, & Crump, 2003; Moutafi et al., 2005). One confound could have been that several of the studies were conducted in student samples. This may have artificially created negative associations because individuals with low *g* and low Conscientiousness were lacking from the samples (due to university selection). Nevertheless, only three of the eight studies reviewed by DeYoung (2011) involved only university students. The association was also found in the large non-student samples of Moutafi and colleagues (2003).

In addition to the overall association, Moutafi et al. (2003) found that the Orderliness facet of Conscientiousness in particular had a negative correlation with *g* (r = -.18), which they argued may be because lower-intelligence individuals use planning and organization to compensate for their disadvantage on intellectual tasks (see also Chamorro-Premuzic and Furnham, 2006). The PT scale Tidiness was related on a content basis to Orderliness by Reeve et al. (2006); therefore, we hypothesized that it would have a negative correlation with intelligence. The PT scale Mature Personality was also related to Conscientiousness by Reeve et al. (2006), hence we also predicted a negative association for it.

Big Five Agreeableness has typically not been found to have significant correlations with intelligence (Ackerman & Heggestad, 1997; DeYoung, 2011); hence we did not make any directional hypothesis regarding the PT scale Social Sensitivity, which was the only PT scale with a high correlation with Agreeableness according to Reeve et al. (2006).

Possible Nonlinear Associations

Although nonlinear associations between intelligence and personality have rarely been found, some suggestive evidence for nonlinear associations has been found in research on gifted children and adolescents. This has primarily been done with the Myers-Briggs Type Indicator (MBTI; Myers, McCaulley, & Most, 1985).

Sak (2004) performed a meta-analysis of 14 studies of gifted adolescents, mostly identified through talent searches using the SAT and selection into gifted programs. He found that gifted adolescents were substantially more likely to fall on one side of the dichotomous MBTI dimensions than a norm group of students (Sak, 2004). Gifted adolescents were more likely to select Introversion over Extroversion (48.7% compared to 35.2% in the non-gifted sample), Intuition over Sensation (71.6% compared to 31.9%), and Perceiving over Judging (60.1% compared to 45.4%), as well as marginally more likely to prefer Thinking to Feeling (53.8% compared to 47.5%; Sak, 2004). Studies in adults have found that MBTI Extroversion to be strongly related to Big Five Extraversion ($r = .74$), whereas Intuition is strongly related to Openness to Experience ($r = .72$). MBTI Thinking is negatively correlated with Agreeableness ($r = -.44$) and Perceiving negatively correlated with Conscientiousness ($r = -.49$) (correlations for the male sample in McCrae & Costa, 1989). Therefore, by extension it can be predicted that gifted adolescents may be substantially higher in Openness to Experience and lower on Extraversion, Agreeableness and Conscientiousness than non-gifted adolescents. A recent study of Israeli adolescents, who were selected as the top 1% to 3% of performers on an intelligence test, confirmed this pattern for Openness to Experience ($d = .51$) and Agreeableness ($d = -.28$), and also showed that gifted adolescents were lower in Big Five Neuroticism than non-gifted adolescents ($d = -.26$) (Zeidner & Shani-Zinovich, 2011). Group differences in Conscientiousness and Extraversion were in the expected direction based on MBTI studies, but non-significant (Zeidner & Shani-Zinovich, 2011).

The presence of some substantial mean differences between gifted and non-gifted groups suggests that average personality level might differ to an expanding (e.g. exponential) degree with increasing ability level, although it is possible that linear effects could produce these effects as well. Exponential functions may most closely approximate differences in certain personality traits with increasing ability level, but such trends would also be captured by quadratic effects, at least for one side of the parabolic curve. One issue relating to this testing is that some studies have also found increases in personality variance with higher intelligence (e.g. in the MBTI; Myers, McCaulley, & Most 1985). This may violate the assumption of homogeneity of variance underlying generalized linear models, although these models are robust to some level of heteroscedasticity (Tabachnick & Fidell, 2007). It is possible that higher cognitive ability is causally linked to increases in personality variance, as intelligence potentially facilitates more flexible adjustment of personality to the environment; however, here we focused on mean-level changes in personality.

Given the evidence in the gifted literature, we hypothesized that positive quadratic trends would be observed for the PT scales associated with Openness to Experience (Culture and Leadership) as well as Emotional Stability (Calmness and Self-Confidence). We also predicted that negative quadratic effects (an inverted-U shape) would be observed for the scales associated with the social closeness aspect of Extraversion (Sociability), Agreeableness (Social Sensitivity), and Conscientiousness (Tidiness and Mature Personality). Because less is known about personality in low-ability groups, these predictions were based on the trend for above-average intelligence.

Method

Sample

Project TALENT participants were obtained by a stratified random sample of all public and private high schools in the United States in 1960 (Flanagan et al., 1962). The PT dataset was thus a nationally-representative sample of approximately 5% of the student population. The full sample consisted of 376,213 students, with approximately 100,000 students in each grade from 9 through 12. Of the full sample, 50.13% was female. The age range was from a mean of 14.4 in grade 9 (SD = .78) to 17.3 in grade 12 (SD = .67). The full individual age range was 8 to 21.

Intelligence Measures

The intelligence measures for the current study were selected from the PT aptitude and achievement tests, using the broad selection of 37 tests as defined in a previous study (for descriptions of the tests and reliabilities see Major, Johnson, & Deary, 2012; see also Flanagan et al., 1962).

The data screening methods for the intelligence tests were the same as used by Major, Johnson and Deary (2012). Scores on the PT response credibility index, which was based on a screening test assessing illiteracy, mental disability or an apathetic testing attitude, were used to exclude participants who did not reach the cut-offs set by the PT study designers, except where only mental slowness was indicated (a low score for the number of responses on the Clerical Checking test). Transformations were applied to three tests that displayed non-normal distributions (Capitalization, English Usage and Table Reading), and cases showing severe problems with multivariate outliers were removed (Major, Johnson & Deary, 2012). Following data screening of the intelligence tests, total sample size was reduced to 366,939 (2.47% of the sample removed, the vast majority for low screening scores).

Personality Measures

The PT personality scale scores were derived from 108 items that asked students how typical certain personal attributes and behaviors were of them. Table 2 contains sample items for the scales; reliability coefficients from Reeve et al. (2006) are presented due to their lack of availability from the original study. The responses to personality items were on five-point Likert scale. The only scores available in the PT dataset were scale scores, which were obtained by assigning a score of 1 to items where the student indicated that the item described them “extremely well” or “quite well” (the two most affirmative responses), and a score of 0 to other responses (“fairly well”, “slightly”, or “not very well”). The converse scoring method was used for negatively-phrased items (Wise, McLaughlin, & Steel, 1979).

The common personality factor.

The correlations among the raw PT personality scale are displayed in Table 3. Across the eight samples (four grades by two genders), the first common factor accounted for a mean of 41.3% of variance (SD = 2.2%). Potential sources for this common variance included artifacts such as method variance (e.g. due to pencil-and-paper testing), acquiescence bias and socially-desirable responding, and non-artifactual true score variance.

Although it was not possible to disentangle these sources directly, some evidence suggested that this common variance was potentially confounding the relations of personality scales with *g*. Several personality scales displayed unexpectedly positive correlations with *g*. The Tidiness scale, which Reeve et al. (2006) identified on a content basis with the Orderliness facet of Conscientiousness, displayed a positive correlation with *g* in all samples (mean r = .16 in males, .10 in females). This observation contradicted the finding of Moutafi et al. (2003) that Orderliness was negatively associated with *g*, as well as the finding that Conscientiousness in general was negatively related (DeYoung, 2011). Similar inferences could be drawn for the Sociability and Impulsiveness scales, which were predicted to have negative associations with *g* based on the literature, but instead showed small positive correlations (Sociability: *r* = .09/.05 in males/females; Impulsiveness: r = .03/.10 for males/females)[1]. We hypothesized that the positive correlation between the common factor and *g* could account for these positive correlations (mean r = .28 in both males and females).

In order to aid in the interpretation of the common factor in the PT personality scales, we performed a re-analysis of the college sample data from Reeve et al. (2006)[2]. The general factor from the PT scales, extracted through maximum likelihood estimation, explained 25.9% of the variance in the college sample. The factor was then correlated with the individual items (item-level data were not available in PT). The Vigor scale was over-represented in items that correlated most highly with the common factor: six of the seven items assessing Vigor were in the top 10 most highly-correlated items, including the most highly correlated item (“I am energetic”, r = .63). The Vigor scale also had the highest loading on the common factor (.71) in the college sample. In addition to this trend, only 23 of the 108 personality items (21%) contained statements that referred to other people’s views (e.g. “people consider me sociable”), but 8 of these items were in the top 20 most correlated with the common factor (40%). This finding suggested that items that primed reputational

[1] The correlation between Impulsiveness and *g* in grade 9 males was non-significant, however.

[2] Data obtained through personal communication (September 18, 2012).

concerns were more closely tied to the common factor. In the college sample, the factor was most highly associated with items that seemed to tap the form of socially-desirable responding that has been termed egoistic self-enhancement (Paulhus & John, 1998). Several of the PT personality scales, notably the Self-Confidence, Vigor and Leadership scales, had labels and contents similar to the Extraversion facets that have displayed egoistic bias (Ashton & Lee, 2010). Some of the other scales could be seen as socially-desirable blends of Big Five factors: for example, the analysis of Reeve et al. (2006) suggested that the Culture scale was a blend of high Openness to Experience and Agreeableness (see Table 1). One notable difference between the college sample and the PT samples was that a lower loading was seen for Tidiness (.29, compared to .70 in PT). This finding indicated that Tidiness was more integral to the common factor in PT than in the college sample.

Regardless of whether the correlation between the personality factor and *g* was artifactual or not, our primary interest was in the relations of the individual scales with *g*. Therefore, we chose to perform the main analysis while removing the influence of the common variance from the scales. The scales were regressed onto the common factor, and residuals retained for the further analyses. Table 4 displays the correlations in grade 10 males and females.

To verify that the residualization did not damage the convergent validity of the PT scales we examined their correlations with the predicted IPIP Big Five scales in the college sample. Compared to the mean correlation of the unresidualized scales ($r = .56$, $SD = .13$), the mean correlation decreased to $r = .36$ ($SD = .19$). This reduction was consistent with the high correlation of the common factor in the PT scales with the common factor in the IPIP scales ($r = .77$). When the variance in the PT factor that was explained by the IPIP factor was removed (through regression) prior to using it to residualize the PT scales, there was no reduction in the correlation between the residualized PT scales and the IPIP scales (mean r =

.56, SD = .12). Thus, removing the PT common factor appeared to reduce the convergent validity of the PT scales, but this seemed to be because the IPIP and PT scales shared rater variance, captured by their common factors, which inflated the initial correlations.

When the scales were residualized for the common factor, they displayed some problematic non-normality and outliers. Outliers were capped at four standard deviations above and below the mean (approximately the most extreme score expected in our samples). The scales Impulsiveness and Leadership displayed positive skewness in all samples, therefore a square-root transformation (with reflection) was applied to them. Following these transformations, all personality scales displayed adequate normality (all skewness and kurtosis z values below 0.5). In contrast to the raw scales, the mean correlation between the residualized scales was slightly negative, and ranged from -.096 (SD = .12) in grade 11 females to -.099 (SD = .09) in grade 9 males.

Methods of Analysis

We searched for linear and nonlinear associations between *g* and the personality scales in two ways. The first method was to estimate linear and quadratic effects using latent moderated structural equation modeling (LMS; Klein & Moosbrugger, 2000). LMS directly models the quadratic term as the interaction of a latent variable with itself (or the square of the variable), and corrects for the multivariate non-normality of the term, making it a better method than regression (Harring, Weiss & Hsu, 2012; Moosbrugger, Schermelleh-Engel, Kelava & Klein, 2009). LMS was performed in Mplus 5.21.

Secondly, we ran generalized additive models (GAMs; Hastie & Tibshirani, 1986), using the R package ‘mgcv’(Wood, 2006). A GAM is a generalized linear model in which the linear predictor depends on unknown smooth functions of the predictor variables. The smooth functions are represented by regression splines with a particular basis function (for our analyses, the cubic basis was selected). The degree of smoothing of the spline is determined by the generalized cross validation score, which is a measure of how well the spline fits across datasets with each datum left out in turn (see Wood, 2006, for more details). We used GAMs to explore other possible nonlinear trends apart from quadratic trends between the personality scales and *g*.

Using the LMS and GAM approaches, we estimated the effects of *g* on the ten personality scales in each of eight samples divided according to grade and sex. We selected the direction of effect of *g* on personality because we preferred this direction theoretically and because *g* was more reliably measured than the personality variables. In addition, it was not possible to estimate latent personality traits because of the lack of item-level data. Thus, using *g* as a predictor allowed for LMS estimation of quadratic effects.

The measurement model employed for *g* was the VPR model, which has been shown to fit well to these data (Major, Johnson & Deary, 2012). Reeve et al. (2006) employed a different hierarchical model for *g* with a selection of 13 PT tests. In order to verify that the results would be comparable with either model, we correlated the *g* factor scores of the two models in the grade-12 sample (the sample used by Reeve et al.). The correlations were .93 in males and .94 in females, indicating a high level of correspondence. The VPR model was used because it was a more comprehensive and better-fitting model of the PT intelligence tests. We could have instead used the IQ composite provided by PT investigators, which correlated approximately .70 with the VPR *g* factor, but we regarded the VPR-*g* as a better measure of general intelligence, and it also allowed for a latent-estimation approach.

The variance explained by each effect in the LMS models was obtained by subtracting the residual variance of the personality scales from 1 (as the personality scales were standardized). GAMs were estimated with *g* factor scores obtained from the VPR model.

Missing data were handled with through direct maximum likelihood estimation, which requires the assumption the data were missing at random (MAR). This assumption was tenable in PT because it is unlikely that students purposely avoided particular aptitude tests or the personality scales. In addition, only 2.3 to 3.2% of the ability test scores and 1.0 to 3.5% of the personality test scores were missing in each sample.

Results

Tables 5 and 6 display the standardized linear and quadratic effects of *g* on the original personality scales for males and females, respectively, while Tables 7 and 8 display the effects for the residualized personality scales. Figure 1 (males) and Figure 2 (females) illustrate the predicted mean-level differences in residualized personality based upon the estimated linear and quadratic effects in the grade 10 samples. Social Sensitivity in males and Calmness in females were omitted from the figures due to the lack of significant linear or quadratic effects. The grade-10 samples were chosen for illustration because they represented an intermediate age for the PT high school students. Due to their intermediate age, the effects in both the grade-10 and grade-11 samples were close in size to the average effect across all samples; grade 10 was chosen because it had the larger sample size.

For the original scales, *g* had significant positive linear associations with all the personality scales in all samples, except for Impulsiveness in grade-9 males. In males, the most notable associations were with Calmness (beta = .246 to .264) and Mature Personality (beta = .230 to .273); in females they were with Culture (beta = .226 to .254) and Mature Personality (beta = .264 to .288). The quadratic effects of *g* on the personality scales were also significant in most cases. However, substantial quadratic effects could be defined as those accounting for approximately 2% of the variance or greater. By this criterion, the only substantial quadratic effect observed in the original scales was a negative quadratic effect of *g* on Sociability, observed in all samples. In females, there was a negative quadratic effect on Tidiness that reached the 2% criterion in grade 12.

For the residual scales in males (Table 7, Figure 1), the largest linear effects of *g* were on Sociability (beta = -.042 to -.130), Calmness (beta = .076 to .104), and Self-Confidence (beta = .106 to .131). Substantial negative quadratic effects (R^2 of approximately 2% or greater) were observed for Sociability (beta = -.146 to -.159) and Vigor (beta = -.107 to -.116). Positive quadratic effects were observed for Mature Personality (beta = .099 to .119) and Leadership (beta = .106 to .124).

In the female samples (Table 8, Figure 2), the largest linear effects of *g* were on Sociability (beta = -.077 to -.195), Tidiness (beta = -.064 to -.163), and Mature Personality (beta = .075 to .140). Substantial negative quadratic effects were seen on Sociability (beta = -.140 to -.155) and Tidiness (beta = -.064 to -.163), and a positive quadratic effect was found on Mature Personality (beta = .075 - .140).

Table 9 contains a summary of our hypotheses compared to the observed associations for the residualized scales. Of our nine hypotheses about the linear effects of *g* on the personality traits, five were supported in all male samples (positive: Calmness, Self-Confidence; negative: Sociability, Tidiness, Impulsiveness), and one more received support in some grades (the positive effect on Vigor)[3]. In females, four hypotheses were supported (positive: Culture, Self-Confidence; negative: Sociability, Tidiness) and two had mixed support (the positive effect on Vigor and negative effect on Impulsiveness).

[3] The negative linear effect of *g* on Tidiness in grade 9 males was only significant at $p < .05$, and hence would not survive correction for multiple testing. Due to the effects in the other three samples, however, we counted this effect as significant when considering all samples.

The most unexpected linear association was a negative linear effect of *g* on Leadership in both males and females. This effect, in combination with the positive quadratic effect of *g* on Leadership, resulted in the highest levels of Leadership being observed for those with low *g* (see Figures 1 and 2). This finding may be less trustworthy than the others, however, because the Leadership scale only contained five items, and displayed borderline reliability (alpha = .65) in Reeve et al. (2006). We reserve interpretation of the meaning of the effects for the Discussion.

Of our eight predicted quadratic effects, four were supported in male samples (positive: Culture, Leadership; negative: Sociability, Tidiness), and six were supported in female samples (positive: Culture, Self-Confidence, Leadership; negative: Sociability, Social Sensitivity, Tidiness). The most important deviation from our hypotheses was for the Mature Personality scale, which was predicted to have a negative quadratic association with *g*, but instead had a positive one in both males and females.

LMS Results Compared to GAM Results

Figure 3 shows a comparison of the fitted functions in the LMS and GAM models for the example of Sociability in grade-10 males (residualized scores). As can be seen, the predicted personality levels are similar in both models. In general, visual inspection of GAM-predicted values showed a close correspondence with LMS results, indicating that a combination of linear and quadratic effects gave a good approximation of the relations revealed by the GAMs (other graphs of the GAMs are available from the first author). In addition, the R^2 for the GAMs were consistent with the variance explained by the combination of the linear and quadratic effects of LMS (slightly more variance was accounted for in the LMS models due to the use of a latent *g* factor instead of factor scores).

For the GAMs in males, the three personality traits where *g* predicted the most variance were Sociability (3.3%), Leadership (2.1%) and Tidiness (1.7%). In females it was Sociability (4.4%), Mature Personality (3.7%), and Tidiness (2.5%). The variance explained in the personality scales was higher for females than males in a number of cases, although this varied greatly across scales (see Tables 7 and 8).

Grade and Sex Differences

The comparison of grade and sex differences in the estimated personality-intelligence relations requires the assumption of measurement invariance between the samples for intelligence and personality. This assumption could not be tested for the personality scales due to lack of item-level data. In addition, measurement invariance testing revealed that although configural and weak invariance were tenable across grade and sex for the VPR model, strong invariance (equality of the intercepts) was not supported in both cases, as indicated by an decrease in CFI > .010 (Cheung & Rensvold, 2002). Therefore, the differences in personality-intelligence relations across samples must be interpreted with caution, as they may be attributable to differences in the measurement of intelligence (or personality).

With this caveat in mind, there were some differences in the measured relations across grade. Notably, the linear relation of Sociability with *g* was more negative with increasing grade level (comparing grade 9 to grade 12 in males: Δ beta = -.88, log-likelihood ratio test: $\chi2$ (1) = 263.58, p < .001; in females: Δ beta = -.118, $\chi2$ (1) = 514.98, p < .001). Two other important trends were the reduction of a negative association of Leadership with *g* at higher grades (in males, Δ beta =.106, $\chi2$ (1) = 387.06, p < .001; in females, Δ beta = .080 $\chi2$ (1) =

233.40, $p < .001$) and an increase of the negative association of *g* with Tidiness (in males, Δ beta = -.075, $\chi2$ (1) = 189.34, $p < .001$; in females, Δ beta = -.099 $\chi2$ (1) = 364.73, $p < .001$).

Discussion

In this study we examined linear and quadratic associations between *g* and personality in Project TALENT. SEM and generalized additive modeling were used to estimate linear and quadratic effects of latent *g* on ten personality scales. In the main analysis used for interpretation, the influence of the general factor of personality was controlled by residualizing the personality scores for the common factor. A review of literature provided us with seventeen hypotheses of linear and quadratic associations; nine of these hypotheses (53%) received support in all male samples and ten (58%) received support in all female samples. In this section, we first review the observed associations and discuss in greater detail some of the unexpected and theoretically-relevant results, focusing on the residualized scales. We then outline limitations of the study, and the implications of our results for future research.

When considering linear associations, the results were mixed but consistent in the majority of cases with previous findings on intelligence-personality associations in samples of the general population (Ackerman & Heggestad, 1997; Wolf & Ackerman, 2005; DeYoung, 2011; Moutafi et al., 2005). As hypothesized, we found that PT participants with higher *g* tended to score higher on Self-Confidence: a scale that reflected both higher social potency (Wolf & Ackerman, 2005) and lower Neuroticism in Five-Factor terms (Reeve et al., 2006). In addition, there was also a positive association between *g* and Calmness in males, indicating another positive relation with Emotional Stability. For the scales likely reflecting Extraversion, PT participants with higher *g* scores tended to display lower Sociability (Wolf

& Ackerman, 2005), and Impulsiveness (Pincombe et al., 2007). We found some indirect support for lower Conscientiousness among more intelligent adolescents (for Tidiness, but not Mature Personality), as observed by DeYoung (2011).

Unexpectedly, the scales reflecting Openness to Experience, Culture and Leadership, both had negative linear associations with *g* in males, though Culture was positively related to *g* in females. The Mature Personality scale also displayed a positive association where a negative one was hypothesized. Nonetheless, as discussed below, some plausible reasons for these contradictions can be found when considering the nonlinear associations that were observed, as well as the specific contents of the scales.

In divergence from previous studies (Austin et al., 1997; Austin et al., 2002; Reeve et al., 2006), which did not do so, we found significant quadratic associations of *g* with aspects of personality. A number of the quadratic effects we hypothesized based on the gifted literature were born out (Sak, 2004; Zeidner and Shani-Zinovich, 2011). These nonlinear effects indicated that high-*g* participants displayed lower social closeness (Sociability), lower Conscientiousness (Tidiness), and higher Openness to Experience (Culture, Leadership) compared to their same-grade peers. In addition to these associations in both males and females, more intelligent females also displayed higher Emotional Stability (Self-Confidence) and lower Agreeableness (Social sensitivity).

Nonlinear associations accounted for at most 3.9% of the variance, so it would not be appropriate to conclude that prior studies have misled the field in finding only small quadratic associations. Still, the associations we found would have importance in considering mean personality scores of groups differing greatly from average *g*. In our strongest example, using the grade 10 female sample, negative linear and quadratic associations with *g* predicted a mean Sociability level .70 SDs lower (SE = .02) for individuals two SDs above the mean on *g*, compared to individuals of average *g*[4]. Such a difference would generally be considered substantive, though it did not render the mean Sociability level of grade-10 females with high *g* particularly extreme (the mean fell at approximately the 24th percentile of Sociability of the full sample). The group difference due to the linear effect alone would be only .23 SD (SE = .02), implying a mean Sociability level in the 41st percentile. This example illustrates that failing to consider nonlinear relations causes underestimation of the true associations between certain personality traits and intelligence. Thus, nonlinear associations should be considered when focus is on personality in groups with extremely low or high levels of *g*.

It should be noted that due to quadratic associations of *g* with personality, adolescents with low *g* did not necessarily display the converses of the personality associations of those with high *g*, and in fact were more similar in score with high-*g* students than average ability students on a number of scales. For example, like high-*g* students, they averaged lower Sociability and Tidiness. Participants with low *g* were also unexpectedly found to average higher scores on the Mature Personality and Leadership scales than average-ability students.

When the linear and nonlinear results were taken together, we found that g was associated with mean-level differences in all Big Five domains, which is at odds with existing theories of personality-intelligence relations. For example, Chamorro-Premuzic and Furnham (2006) maintain that each of the Big Five should be related to intellectual competence, but regarded Agreeableness as a marginal indicator, and viewed Neuroticism as mainly being related to intelligence through test anxiety, and Extraversion related through test-taking style. The nonlinear effects that we observed for these traits at high *g* levels appeared to contradict this position. In particular, the opposing pattern for Sociability and Leadership (two aspects of Extraversion), are not explained within their framework.

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[4] For individuals with low *g* (two SDs below the mean), Sociability was .24 SDs below the mean.

PPIK theory also does not provide a full account of the broad associations that we observed between *g* and the Big Five. In PPIK theory, *g* is mainly associated with personality due to the involvement of broad cognitive abilities (such as perceptual speed) in particular trait complexes. Notably, crystallized intelligence is thought to contribute to the Intellectual/Cultural trait complex, along with Openness to Experience (Ackerman & Heggestad, 1997; Ackerman & Beier, 2003). However, several associations we observed not be predicted in this framework, such as the association between higher *g* and lower scores on scales reflecting Conscientiousness, as well as the differential associations of *g* with social closeness and social potency (Wolf & Ackerman, 2005).

To summarize, existing theories of personality-intelligence associations do not account for many of the associations that were observed. Overall, the associations were better predicted based on studies of gifted adolescents (Sak, 2004; Zeidner and Shani-Zinovich, 2011). These studies have suggested that high-*g* adolescents are marked by higher Openness to Experience and Emotional Stability, as well as lower Extraversion (social closeness), Agreeableness and Conscientiousness. Given this consistency, it seems likely that considering the developmental differences between gifted and normally-developing children and adolescents may be a good way to develop understanding of personality-intelligence associations, in addition to examining associations in the general population. Although the data in the current study were not longitudinal, examining cross-grade differences may provide some insight into the development of personality-intelligence associations.

Grade Differences

For scales where an association with *g* was found at any grade level, the majority were found in all four grade samples. In males, there were 19 significant linear and quadratic effects: 13 of them (68.4%) were found in all grade samples. In females, 14 of 18 effects (77.8%) were present in all samples. This consistency supports the view that the effects were not due to chance measurement artifacts from individual samples. Nonetheless, there were some substantial grade differences in the magnitude of associations, notably for the linear effects of *g* on Sociability, Tidiness and Leadership. The two former traits have also been the subject of prior theories on personality-intelligence relations (Wolf & Ackerman, 2005; Chamorro-Premuzic & Furnham, 2006).

Wolf and Ackerman (2005) hypothesized that higher social closeness may run counter to the development of intelligence because adolescents with a greater initial need for social closeness select social activities more frequently than solitary intellectual activities, inhibiting the development of intelligence (Wolf & Ackerman, 2005). In the current study, we observed that *g* was more negatively predictive of Sociability with increasing age or grade level. This finding suggests instead that higher initial intelligence may lead to lower social closeness over time as high-*g* students increasingly select more solitary activities over social ones. Due to the unavailability of item-level data, the PT personality scales were not well-suited to testing the effect of personality on intelligence (the effect hypothesized by Wolf & Ackerman, 2005). Future research may be able to disentangle these two effects by comparing the sizes of quadratic effects in each direction.

A different explanation is called for when attempting to explain the lower Sociability of low-*g* adolescents. One speculation is that lower intelligence may lead to some degree of social ostracizing from peers. This possibility could also be applied to high-*g* adolescents, as their interests are likely to differ from those of their same-age peers.

The negative linear association of *g* with Tidiness became stronger with grade level, which is consistent with the hypothesis of Chamorro-Premuzic and Furnham (2006) that lower intelligence leads to the development of greater orderliness over time as a compensatory mechanism to meet environmental demands[5]. This is consistent with the finding of Sak (2004) that gifted adolescents prefer Perceiving over Judging on the MBTI, where Perceiving is negatively correlated with Conscientiousness. It is also interesting to note that the negative quadratic effect of *g* on Tidiness indicated that very low levels of *g* corresponded with decreased Tidiness, possibly because very low intelligence is a hindrance to organization.

Contrary to our hypothesis, *g* displayed a negative linear association with the Leadership scale. This association was much stronger in the younger grades, and in fact became non-significant in grade 12 males. One interpretation of this finding is that it reflected a lack of clear understanding of the items by younger and less able students (e.g. the item "I am influential"). Another possibility is that the students understood the items, but that less intelligent students overestimated their leadership abilities due to lower metacognitive ability to assess their social standing (Kruger & Dunning, 1999). This 'Dunning-Kruger' effect may also apply to our finding of higher scores on the Mature Personality scale for individuals with below-average *g* (due to a positive quadratic trend). Related to this possibility is that less able students may have displayed higher scores on Leadership and Mature Personality due to greater acquiescence. Some research has found that individuals with less education are more likely to acquiesce, and to have greater variation in acquiescence (Rammstedt, Goldberg, & Borg, 2010), a pattern which may be driven by intelligence. Controlling for the common personality factor should have removed much of the variance due to acquiescence bias; however it may not have eliminated it entirely.

[5] We tested this hypothesis alternatively by examining differences in mean Tidiness with the sample split by quintile of *g*. Comparing grade 9 to grade 12 samples, Tidiness increased significantly in every quintile (p <.001), but there was a progressively greater increase in Tidiness corresponding to lower quintile of *g*.

The literature on gifted adolescents implies that higher intelligence may be causally involved in the development of personality differences in each of the Big Five domains. In terms of age trends in the current study, evidence for this was only encountered for the Sociability and Tidiness scales, facets of Extraversion and Conscientiousness. Nonetheless, these findings suggest that a detailed analysis of age differences in personality-intelligence associations can be helpful in uncovering possible developmental influences.

Unexpected Associations

Due to the positive association between Mature Personality and Conscientiousness in Reeve et al. (2006), and the negative association of *g* with Conscientiousness in the literature, we predicted a negative quadratic effect of *g* on Maturity. The unexpected positive quadratic effect may reflect the fact that the Mature Personality scale contained several items that tapped self-assessed achievement striving and engagement ("I work fast and get a lot done"; "I am productive"). Reeve et al (2006) also identified this scale with the Achievement Striving facet of Conscientiousness. Thus, it may not be so surprising that students with higher *g* scores (who also tended to have had more success at school) also obtained higher scores on this scale, possibly despite its association with overall Conscientiousness, on which they could have scored lower.

Most of the linear and quadratic associations we observed were present in both sexes. The exceptions to this were for linear associations of *g* with Culture, Impulsiveness and Calmness, and a quadratic effect on Social Sensitivity that was only present in females. Based on the content of the Culture scale and its positive association with Big Five Openness (Reeve et al. (2006), we predicted that Culture would show a positive association with *g*. This was the case in females, but small negative associations were found in males (beta = -

.067 to -.087). This may reflect the fact that the Culture scale emphasized having good manners over intellectual interests. Perhaps the socialization pressures on girls to be well-mannered were stronger than those on boys. The other sex differences we observed were less readily interpretable.

A focus on high-g participants may also provide explanations for some of the contradictory linear associations. Based on the association of Culture and Leadership with Openness to Experience (Reeve et al., 2006), we anticipated positive associations of these scales with g, but these were both negative in males, and Leadership was negatively associated in females. However, due to positive quadratic effects of *g* on Culture and Leadership, individuals with high-*g* were above-average on these scales compared to those at average *g* levels (see Figures 1 and 2). The quadratic effects suggest that these mean scores on these scales may only be above-average once a certain threshold of intelligence is reached.

Limitations

There are several limitations surrounding our conclusions regarding personality-intelligence relations. First, our personality scales may not have been measurement invariant across different levels of *g*, which could have caused apparent linear and nonlinear associations that did not exist (McLarnon & Carswell, 2012; Waiyavutti, Johnson, & Deary, 2012). We had, however, no way to test this as we did not have access to the items. Second, we were able to establish that measurement invariance did not hold across samples for *g*. Thus, although we observed some consistency of associations across grades and sexes, the constructs measured across the samples may not have been identical.

The PT personality data had a large common factor that accounted for approximately 40% of the variance in each sample. Our removal of it may have been a limitation because it may have contained substantive personality variance, although most recent research supports a largely artifactual origin of the common factor (Anusic et al., 2009; Ashton et al., 2009; Bäckström et al., 2009; Chang et al., 2012). The analyses without the removal of the common have also been presented so the reader can assess the importance of the decision and interpret its effects.

One possible explanation for the large factor in Project TALENT is that the context of in-school testing may have influenced students to “fake good” on the personality scales, and the more intelligent students were more capable and/or more motivated to do so. Given that the main purpose of PT (of which the students were aware) was to assess scholastic talent, it would be most relevant for students to exaggerate scores on scales tapping behaviour socially desirable in the school context (such as diligence and responsibility). The high loading of the Mature Personality scale on the common factor (mean r = .79) was consistent with this interpretation, as was the relatively higher loading of Tidiness on the common factor in PT samples compared with the college sample of Reeve et al. (2006). A possible non-artifactual explanation is that more intelligent students were in fact more successfully socialized within the high school environment, and that this led to higher scores on all the PT personality scales. Discounting this, however, studies of students selected for high intelligence found that they did not score higher than unselected students on Agreeableness and Conscientiousness—Big Five factors that reflect greater socialization (Sak, 2004; Zeidner & Shani-Zinovich, 2011). In addition, the alternative of including the common factor appeared to maintain overly-positive *g*-personality associations.

Controlling the common factor in the current study caused a number of the personality scales to have negative linear associations with g, in contrast with the results of Reeve et al. (2006), who found only positive linear associations. Nonetheless, out of eight positive-direction associations in Reeve et al. (2006), six were also found here. The exceptions were the positive associations of *g* with Social Sensitivity and Calmness in females.

Nonetheless, one key implication of our results is that the common factor can be a potentially important confounder or mediator of personality-*g* associations; particularly for linear associations as these relations were the most affected by removal of the common factor. If the factor represented at least partly substantive variance instead of methodological variance, it could have been a mediator, whereby the effect of *g* on personality occurred indirectly through it, or vice-versa.

A fourth limitation is that the influence of *g* on personality may also reflect the effects of a third variable on both, such as socioeconomic status, neighborhood or ethnicity. Future research could examine the role of these possible confounds, though it was beyond the scope of the current study.

Finally, the PT sample was assessed in 1960, and relations between personality and intelligence may have shifted since then. This kind of change was observed by Wolf and Ackerman (2005), who that the relation between Extraversion and intelligence was slightly positive before 2000, but slightly negative after 2000. One notable source of such change concerns the erosion of gendered occupational roles since then. Girls at that time had less opportunity to aspire to high education, and especially to occupational achievement in their own names. Moreover, it was very common that they aspired and expected to marry and be supported financially by their husbands. Offsetting the age of the sample, one of the strengths of the Project TALENT sample was that it was representative of the United States in 1960 (Flanagan et al., 1962), so that our results can be generalized to the whole population at that time.

Conclusions and Future Directions

We found that mean levels for most Project TALENT personality scale scores varied substantially across levels of *g*, and a number of scales showed quadratic associations, most notably Sociability. These results provide further support for the view that personality-intelligence associations are substantive and likely relevant to understanding the development of individual differences in both domains (Ackerman, 1996; DeYoung, 2011; Sak, 2004). In particular, we observed that general intelligence might have important roles in creating relative decreases in social closeness (Sociability) and orderliness (Tidiness) across adolescence. Despite the large sample, these results should be considered preliminary until they are replicated in other studies.

The results also indicated two directions for future research in this area: the interpretation of the "general factor of personality", and the use of nonlinear models to test the direction of effect (personality on intelligence, or intelligence on personality).

The common factor had a substantial effect on personality-intelligence relations in the current study due to its positive association with *g*. We made the decision to control for it in the main analysis. Future research should examine whether this relation is substantive or artifactual in nature, possibly through the use of multiple raters or social-desirability scales. If the common factor itself is found to be largely artifactual, as much recent research suggests, then it is questionable whether its overlap with *g* can represent meaningful variance, but research in this area is still ongoing.

The potential to examine direction of effect deserves more consideration in personality-intelligence research. In the current study, we focused on the associations of the quadratic function of *g* with personality, but such nonlinear associations may be found in the other direction, or in both directions. Although the nonlinear associations we observed were small in terms of variance explained, they were capable of resulting in substantive personality differences for individuals at the extreme ends of the *g* distribution. Nonlinear associations can result in substantive differences in personality at the tails of the intelligence distribution, or differences in intelligence at the tails of personality distribution, which can potentially be informative about how personality and intelligence interact with each other, as seen for the traits of Sociability and Tidiness. In spite of this, it is likely that the direction of influence runs both ways in most cases, and that the strength and direction varies depending on the environment and over time. In order to understand the interplay between personality and intelligence more complex study designs and models are still needed.

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Table 1

Associations of the Project TALENT Personality Scales with the Big Five

PT scale	NEO-PI-R facet assignment	Big Five trait loading(s)[a]
Sociability	Gregariousness (E)	E (0.69), A (0.38)
Calmness	Anger (ES) - reversed	ES (0.69)
Vigor	Activity (E)	E (0.43)
Social sensitivity	Sympathy (A)	A (0.81)
Tidiness	Orderliness (C)	C (0.79)
Culture	Aesthetics (O)	O (0.51) A (0.44)
Self-confidence	Self-consciousness (ES) -reversed	E (0.60) ES (0.60)
Mature personality	Achievement Striving (C)	C (0.63) A (0.35)
Impulsiveness	Cautiousness (C) - reversed	E (0.42)
Leadership	Assertiveness (E)	E (0.51) O (0.41)

[a] Loadings obtained in a joint factor analysis of the IPIP and PT scales by Reeve et al. (2006)

Table 2
Personality Test Descriptives

Scale	Sample item	Number of items	Reliability[a]
Sociability	“I like to be with people most of the time”	12	.83
Calmness	“I am usually self-controlled”	9	.81
Vigor	“I am full of pep and energy”	7	.76
Social sensitivity	“I never hurt another’s feelings if I can avoid it”	9	.79
Tidiness	“I like to do things systematically”	11	.85
Culture	“I think culture is more important than wealth”	10	.69
Self-confidence	“I am usually at ease”	12	.79
Mature personality	“I make good use of all my time”	24	.90
Impulsiveness	“I usually act on the first plan that comes to mind”	9	.69
Leadership	“People naturally follow my lead”	5	.65

[a] Reliabilities from the sample of 219 college students in Reeve et al. (2006).

Table 3

Correlations Among the Raw Personality Scales (Grade 10 Males/Females)

	Sociability	Social Sensitivity	Vigor	Calmness	Tidiness	Culture	Self-confidence	Mature Personality	Impul-siveness	Leadership
Sociability	–	.406	.510	.507	.375	.425	.386	.366	.212	.349
Calmness	.448	–	.404	.572	.518	.547	.415	.585	.126	.377
Vigor	.520	.461	–	.428	.370	.436	.317	.468	.250	.392
Social sensitivity	.505	.570	.465	–	.503	.600	.288	.565	.211	.398
Tidiness	.431	.532	.461	.528	–	.573	.251	.608	.075	.324
Culture	.451	.517	.450	.585	.579	–	.310	.605	.192	.419
Self-confidence	.345	.412	.284	.269	.299	.287	–	.374	.127	.316
Mature personality	.433	.606	.545	.593	.632	.586	.390	–	.178	.478
Impulsiveness	.267	.204	.257	.247	.171	.233	.103	.240	–	.249
Leadership	.364	.391	.392	.434	.367	.417	.249	.482	.291	–

Male correlations are below the diagonal, females above.

Table 4

Correlations Among the Personality Scales after Removal of the Common Factor (Grade 10 Males/Females)

	Sociability	Social Sensitivity	Vigor	Calmness	Tidiness	Culture	Self-confidence	Mature Personality	Impul-siveness	Leadership
Sociability	–	.019	.182	-.160	-.160	-.183	.109	-.360	.059	-.035
Calmness	-.037	–	-.169	-.106	-.189	-.120	-.201	-.278	-.007	-.150
Vigor	.114	-.187	–	-.186	-.189	-.183	-.002	-.150	.104	.020
Social sensitivity	-.133	-.106	-.165	–	-.112	-.213	.056	-.164	-.130	-.164
Tidiness	-.162	-.203	-.157	-.155	–	-.052	-.191	-.004	-.179	-.200
Culture	-.127	-.068	-.191	-.202	-.041	–	-.182	-.211	-.047	-.133
Self-confidence	.049	-.194	-.069	.082	-.116	-.143	–	-.081	-.012	.030
Mature personality	-.339	-.261	-.130	-.168	-.080	-.231	-.032	–	-.085	-.040
Impulsiveness	.065	-.037	.035	-.095	-.145	-.048	-.072	-.103	–	.116
Leadership	-.051	-.082	-.043	-.145	-.186	-.092	-.049	-.079	.118	–

Male correlations are below the diagonal, females above.

Table 5

Standardized Linear and Quadratic Effects of g on the Raw Personality Scales (Males)

Trait	Linear effect				Quadratic effect			
	Gr. 9	Gr. 10	Gr. 11	Gr.12	Gr. 9	Gr. 10	Gr. 11	Gr. 12
Sociability								
Beta	.155	.108	.066	.049	-.119	-.118	-.124	-.132
R^2	.024	.012	.004	.002	.021	.020	.023	.025
Calmness								
Beta	.264	.261	.248	.246	–	–	–	–
R^2	.070	.068	.062	.061	–	–	–	–
Vigor								
Beta	.233	.196	.165	.146	-.094	-.091	-.084	-.090
R^2	.054	.038	.027	.021	.012	.011	.009	.011
Social Sensitivity								
Beta	.202	.202	.197	.193	–	–	-.018	-.024
R^2	.041	.041	.039	.037	–	–	.000	.001
Tidiness								
Beta	.212	.188	.142	.114	-.058	-.052	-.061	-.068
R^2	.045	.035	.020	.013	.004	.004	.005	.006
Culture								
Beta	.161	.156	.130	.132	–	.023	.040	.048
R^2	.026	.024	.017	.017	–	.001	.003	.004
Self-Confidence								
Beta	.245	.218	.212	.222	–	–	–	.017
R^2	.060	.047	.045	.049	–	–	–	.001
Mature Personality								
Beta	.273	.255	.241	.230	.044	.051	.054	.044
R^2	.075	.065	.058	.053	.003	.005	.006	.004
Impulsiveness								
Beta	–	.032	.030	.044	–	–	–	–
R^2	–	.001	.001	.002	–	–	–	–
Leadership								
Beta	.060	.071	.093	.116	.084	.080	.073	.065
R^2	.004	.005	.009	.013	.010	.010	.008	.007

Effects greater than .015 are significant at $p < .001$, with no adjustment for multiple testing. Non-significant effects are not shown.

Table 6

Standardized Linear and Quadratic Effects of g on the Personality Scales (Females)

Trait	Linear effect				Quadratic effect			
	Gr. 9	Gr. 10	Gr. 11	Gr.12	Gr. 9	Gr. 10	Gr. 11	Gr. 12
Sociability								
Beta	.129	.075	.028	-.023	-.138	-.149	-.148	-.138
R^2	.017	.006	.001	.000	.030	.033	.033	.030
Calmness								
Beta	.226	.207	.201	.175	-.028	-.033	-.028	-.037
R^2	.051	.043	.040	.031	.001	.001	.001	.002
Vigor								
Beta	.221	.177	.146	.118	-.078	-.088	-.077	-.067
R^2	.049	.031	.021	.014	.008	.011	.009	.006
Social Sensitivity								
Beta	.237	.217	.209	.175	-.060	-.084	-.086	-.086
R^2	.056	.047	.044	.031	.006	.011	.011	.011
Tidiness								
Beta	.176	.121	.086	.032	-.085	-.099	-.103	-.116
R^2	.031	.015	.007	.001	.011	.014	.016	.020
Culture								
Beta	.254	.252	.247	.226	–	-.016	–	–
R^2	.065	.063	.061	.051	–	.000	–	–
Self-Confidence								
Beta	.185	.165	.164	.169	–	–	–	–
R^2	.034	.027	.027	.029	–	–	–	–
Mature Personality								
Beta	.282	.264	.288	.269	.059	.055	.050	.036
R^2	.080	.069	.083	.072	.005	.006	.004	.003
Impulsiveness								
Beta	.071	.119	.113	.117	.040	.046	.021	.023
R^2	.005	.014	.013	.014	.002	.003	.001	.001
Leadership								
Beta	.074	.057	.072	.095	.052	.047	.050	.056
R^2	.005	.003	.005	.009	.004	.004	.004	.005

Effects greater than .015 are significant at $p < .001$, with no adjustment for multiple testing. Non-significant effects are not shown.

Table 7

Standardized Linear and Quadratic Effects of g on the Residualized Personality Scales (Males)

Trait	Linear effect				Quadratic effect			
	Gr. 9	Gr. 10	Gr. 11	Gr.12	Gr. 9	Gr. 10	Gr. 11	Gr. 12
Sociability								
Beta	-.042	-.087	-.118	-.130	-.146	-.148	-.155	-.159
R^2	.002	.007	.014	.017	.032	.034	.037	.039
Calmness								
Beta	.076	.094	.101	.104	–	–	–	–
R^2	.006	.009	.010	.011	–	–	–	–
Vigor								
Beta	.053	.020	–	-.022	-.114	-.116	-.107	-.110
R^2	.003	.000	–	.000	.019	.020	.017	.019
Social Sensitivity								
Beta	-.029	–	.017	.020	–	–	–	-.016
R^2	.001	–	.000	.000	–	–	–	.000
Tidiness								
Beta	–	-.020	-.058	-.086	-.072	-.069	-.084	-.088
R^2	–	.000	.003	.007	.008	.008	.011	.013
Culture								
Beta	-.087	-.073	-.082	-.067	.024	.054	.077	.093
R^2	.008	.005	.007	.005	.000	.004	.008	.011
Self-Confidence								
Beta	.131	.107	.106	.118	–	–	–	.026
R^2	.017	.011	.011	.014	–	–	–	.001
Mature Personality								
Beta	.066	.061	.070	.056	.119	.115	.113	.099
R^2	.004	.004	.005	.003	.022	.021	.020	.016
Impulsiveness								
Beta	-.125	-.076	-.032	-.023	.031	.021	.028	.018
R^2	.016	.006	.001	.000	.001	.000	.001	.000
Leadership								
Beta	-.116	-.094	-.048	–	.124	.113	.107	.106
R^2	.013	.009	.002	–	.023	.022	.017	.016

Effects greater than .015 were significant at $p < .001$, with no adjustment for multiple testing. Non-significant effects are not shown.

Table 8

Standardized Linear and Quadratic Effects of g on the Residualized Personality Scales (Females)

Trait	Linear effect				Quadratic effect			
	Gr. 9	Gr. 10	Gr. 11	Gr.12	Gr. 9	Gr. 10	Gr. 11	Gr. 12
Sociability								
Beta	-.077	-.115	-.161	-.195	-.153	-.155	-.149	-.140
R^2	.006	.013	.026	.038	.036	.037	.036	.031
Calmness								
Beta	–	–	–	–	–	–	–	–
R^2	–	–	–	–	–	–	–	–
Vigor								
Beta	.041	–	–	-.032	-.074	-.077	-.065	-.050
R^2	.002	–	–	.001	.008	.009	.007	.004
Social Sensitivity								
Beta	–	–	.017	–	-.052	-.047	-.079	-.075
R^2	–	–	.000	–	.004	.008	.010	.009
Tidiness								
Beta	-.064	-.105	-.137	-.163	-.092	-.100	-.106	-.120
R^2	.003	.011	.019	.027	.015	.016	.018	.023
Culture								
Beta	.032	.066	.071	.078	.030	.042	.045	.080
R^2	.001	.004	.005	.006	.001	.003	.003	.005
Self-Confidence								
Beta	.047	.040	.034	.055	–	.022	.039	.043
R^2	.002	.002	.001	.003	–	.000	.003	.003
Mature Personality								
Beta	.075	.083	.133	.140	.162	.166	.149	.122
R^2	.006	.007	.018	.020	.041	.042	.035	.024
Impulsiveness								
Beta	-.036	.046	.055	.075	.069	.079	.046	.046
R^2	.001	.002	.003	.006	.008	.010	.003	.003
Leadership								
Beta	-.111	-.109	-.079	-.031	.095	.093	.096	.106
R^2	.012	.012	.006	.001	.014	.013	.014	.017

Effects greater than .015 were significant at $p < .001$, with no adjustment for multiple testing. Non-significant effects are not shown.

Table 9

Hypothesized Versus Observed Effects of *g* on Residualized Personality in All Samples

Scale	Predicted linear	Observed linear	Predicted quadratic	Observed quadratic
Males				
Sociability	–	–	–	–
Calmness	+	+	+	NS
Vigor	+	+/–		
Social sensitivity			–	NS
Tidiness	–	–	–	–
Culture	+	–	+	+
Self-confidence	+	+	+	NS [a]
Mature personality	–	+	–	+
Impulsiveness	–	–		
Leadership	+	–	+	+
Females				
Sociability	–	–	–	–
Calmness	+	NS	+	NS
Vigor	+	+/–		
Social sensitivity			–	–
Tidiness	–	–	–	–
Culture	+	+	+	+
Self-confidence	+	+	+	+
Mature personality	–	+	–	+
Impulsiveness	–	+/–		
Leadership	+	–	+	+

[a] There was a small positive effect in grade 12 male sample. NS = non-significant.

Figure Titles and Captions

Figure 1. Mean Personality as Predicted by General Intelligence (Grade 10 Males).

Caption: Personality scales and *g* are in standard units. Light lines represent 2 standard errors (SEs) above and below the mean (approximate 95% confidence interval). SEs obtained from GAM models.

Figure 2. Mean Personality as Predicted by General Intelligence (Grade 10 Females).

Caption: Personality scales and *g* are in standard units. Light lines represent 2 standard errors (SEs) above and below the mean (approximate 95% confidence interval). SEs obtained from GAM models.

Figure 3. LMS and GAM-predicted Sociability as a Function of General Intelligence (Grade 10 Males).

Caption: LMS estimate = solid grey line. GAM estimate = dashed line. Sociability and *g* are in standard units.

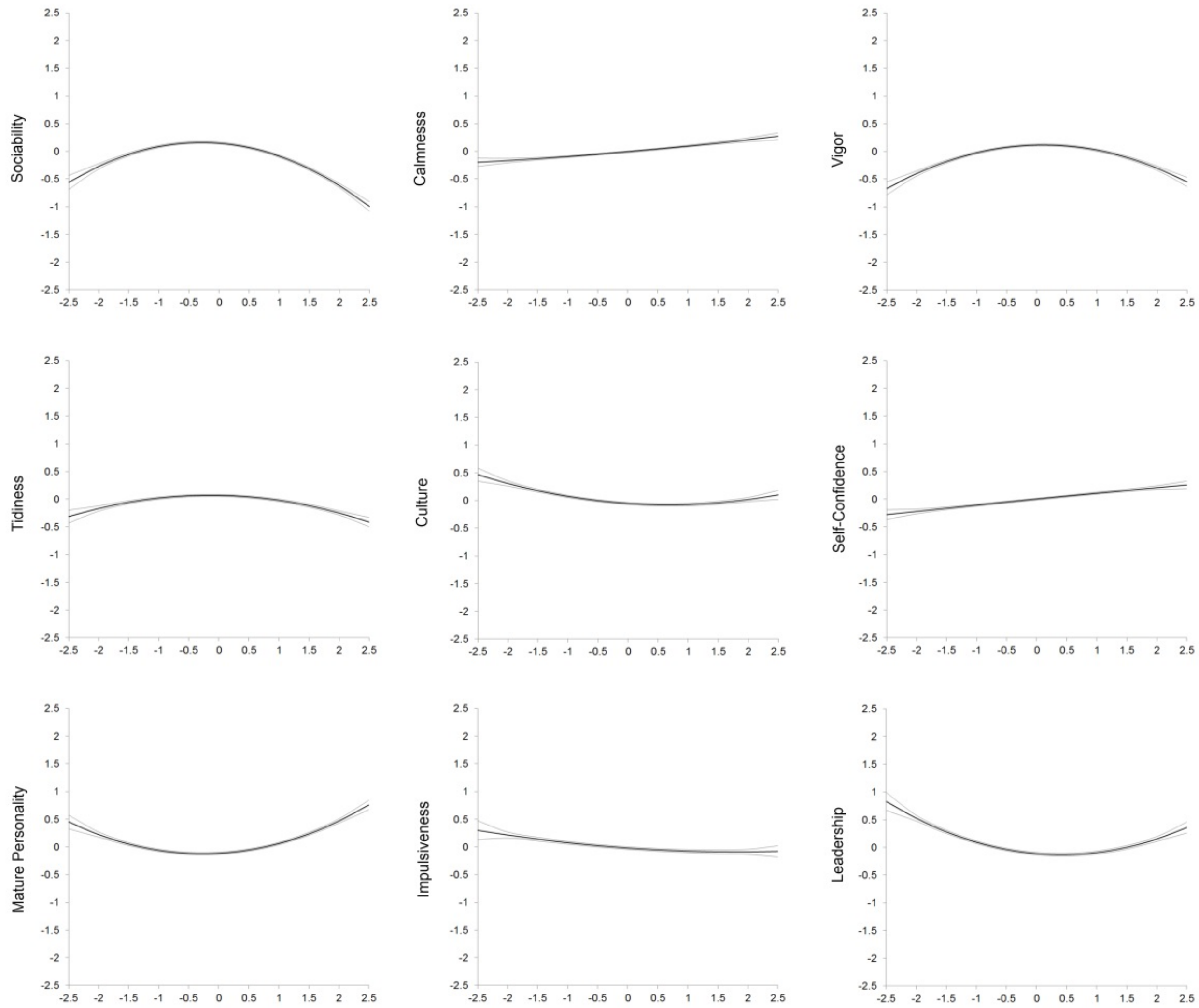
Sociability
Calmnesss
Vigor
Tidiness
Culture
Self-Confidence
Mature Personality
Impulsiveness
Leadership

Figure 1

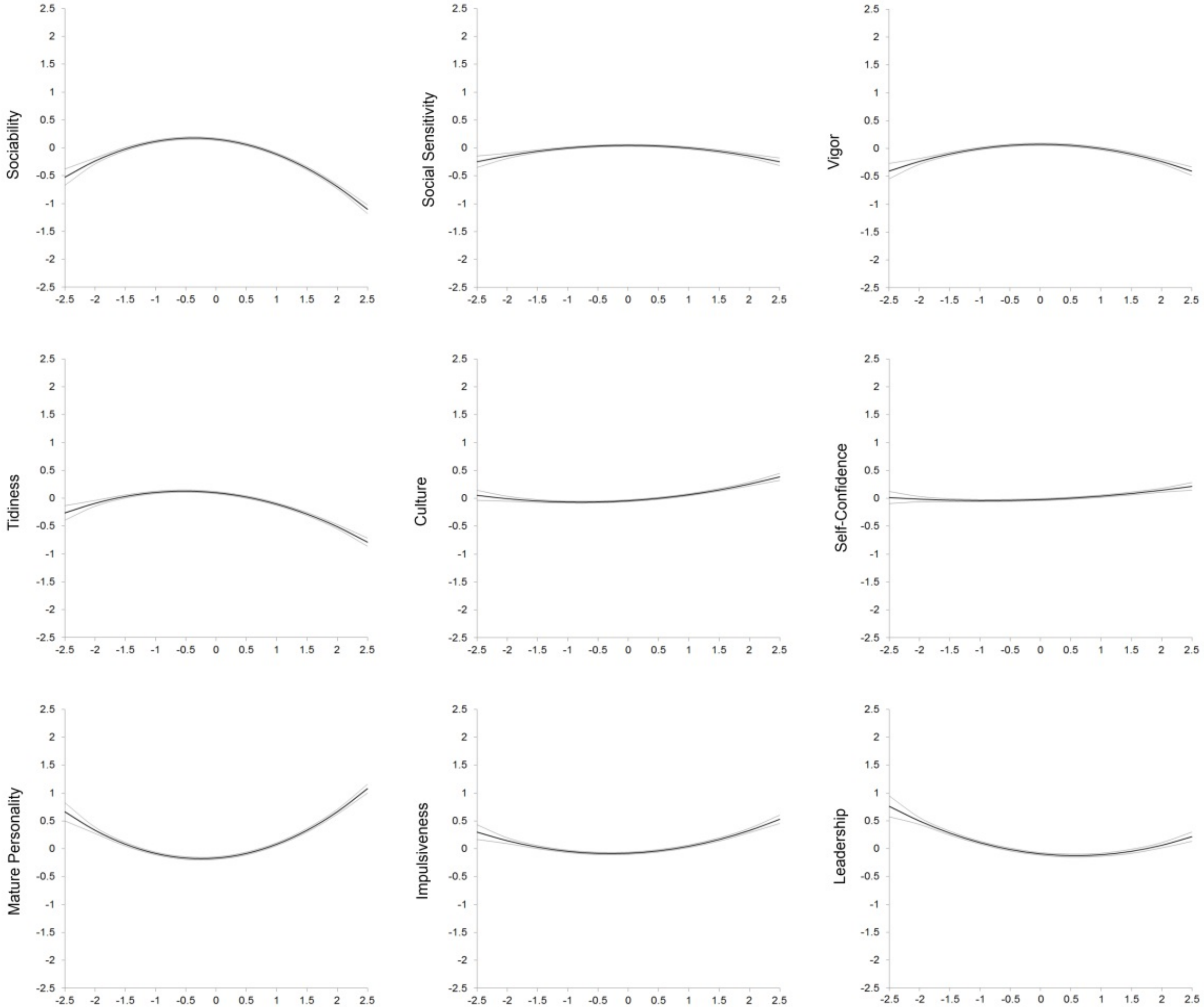
Sociability
Social Sensitivity
Vigor
Tidiness
Culture
Self-Confidence
Mature Personality
Impulsiveness
Leadership

Figure 2

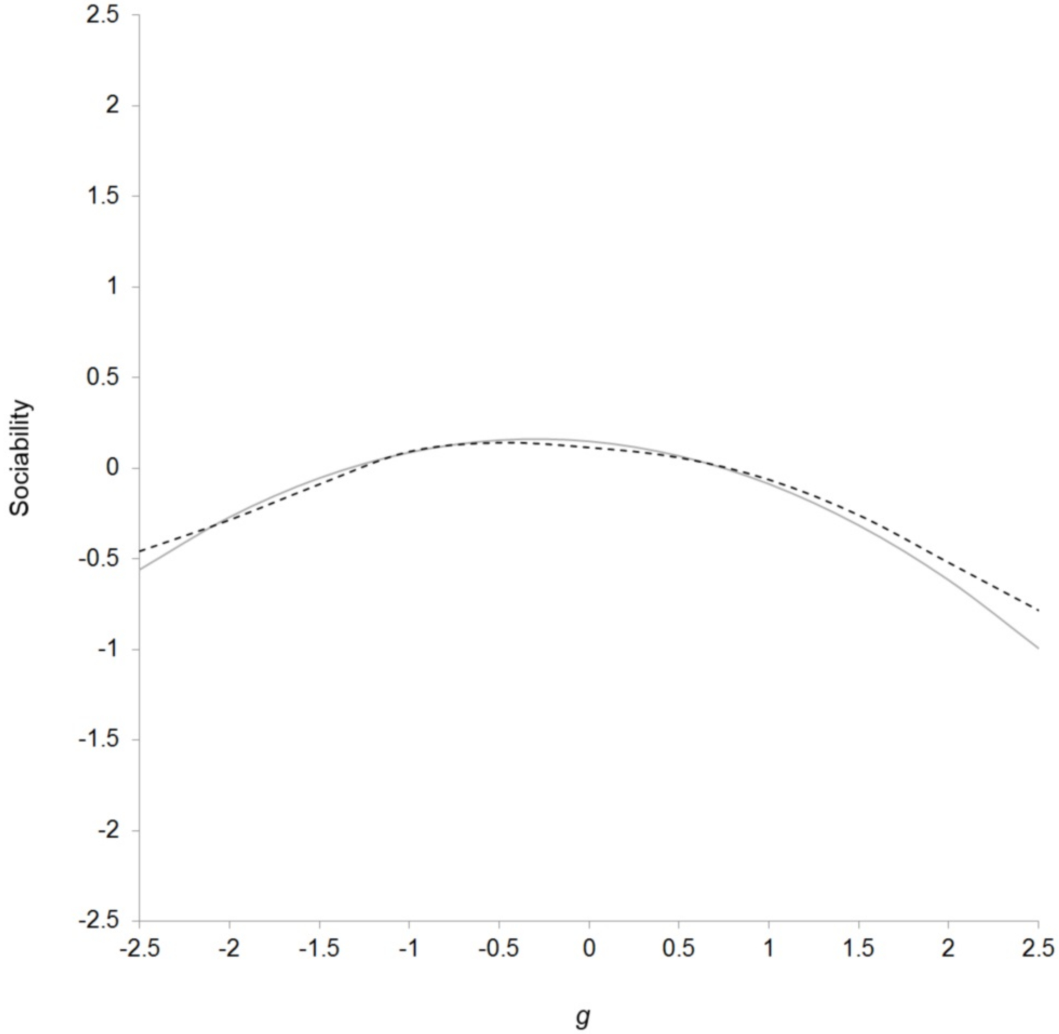

Figure 3